of mathematics and more particularly into mathematical reasoning. These investigations became partly a mathematical analysis of logic itself and partly a logical analysis of the laws followed by the symbols and operations used in mathematics. De Morgan worked in both directions; we have his "Formal Logic" and his "Double Algebra." Operations were studied quite independently of the meaning given to the symbols. Originally the symbols stood for concrete things, and each operation had its concrete meaning. At present symbols are sometimes used without giving them any meaning whatsoever, and without defining them at all, and then the operations for combining these symbols are arbitrarily defined, with the sole restriction that they do not contradict each other.

Each new set of operations thus establishes a calculus. If afterwards any entities can be found which can be combined by operations answering the characteristics of the operations used in the new calculus, then the latter may be employed for a theory of those entities, and its results will allow of an interpretation. These entities themselves may be anything, concrete things, or logical concepts, or ordinary algebraical quantities.

Thus the ground was already prepared for greatly extending the realm of algebra and the scope and power of algebraical operations, when the genius of Prof. Cayley conceived the idea of invariants[1] which has given rise to that marvellous growth of our science which has suddenly brought England again far to the front.

It was known from Gauss's investigations that for quadratic expressions a certain combination of its constants, its determinant, exists, which has the following property.

If the quadratic expression be transformed into another by a linear substitution, then the determinant of the transformed expression is obtained from that of the original expression by multiplying it by a factor which depends solely on the substitution used.

Afterwards Eisenstein discovered that a similar theorem holds for a cubic expression of one variable. These isolated facts suggested to Cayley that combinations of constants having this property must exist for all algebraical expressions. The problem was how to find these.

The manner in which this has been solved I need not restate here, but I wish to call your attention to the fact that the symbolic methods worked out by the school of mathematicians referred to have been of the greatest use in the development of the theory of invariants, which could scarcely have been brought to its present perfection without it.

It would be an impertinence for me to say much either in praise of Prof. Cayley's work or in justification of the Council's choice. Prof. Cayley has invented and worked out the theory of invariants, and in steady life-long work connected it with nearly every branch of mathematics, enriching everything he touches, and everywhere throwing open new vistas of future work.

The Council of the Mathematical Society in selecting Prof. Cayley as the first recipient of the De Morgan Medal, and thus doing homage to his genius, did so not so much with the idea that it could add honour to his name as that they might add honour to the medal by connecting his great name with it, and thus increase its value for all future recipients. And it is befitting that a body like the London Mathematical Society should give formal expression to the reverence and admiration in which it holds the greatest among its members.

PHYSICAL GEOGRAPHY OF THE MALAYAN PENINSULA

AS some remarks of mine on the mountain system of the Malayan peninsula have already appeared in NATURE, perhaps the following summary of the results of ten months' explorations in the State of Perak will be interesting.

The State of Perak is comprised between the sea (Straits of Malacca) and the main central chain which runs along the centre of the peninsula. Its boundaries are, roughly: north, the River Krian; south, River Bernam; west, the ocean; east, the main central chain. The geology may be briefly described as consisting of—

(1) An immense granite formation, rising into extremely sharp and precipitous parallel ridges having nearly a meridional direction. This granite passes frequently into slates and schists. The prevailing colour is blue.

(2) A Palæozoic formation of slates, mottled sandstones, and clays, forming outliers or detached portions. It is found most abundantly at the foot of the ranges, whence it usually dips away conformably to the slopes of the hills and mountains. It has evidently been subject to great denudation.

(3) Limestone in detached outliers, or isolated hills of precipitous character, showing much denudation. It is stratified or crystalline. No fossils have been found yet, but is probably of Palæozoic age. From its wide extension throughout Perak, where it crops out in so many places, it may have once covered the whole of the granite and Palæozoic clays.

(4) Drifts and alluvium from the ancient streams and river beds. These are formed of the material from all the preceding deposits. All the tin deposits of the country are in these drifts. The ore occurs in a manner very similar to the alluvial gold in Australia, that is to say, in "leads," which are the ancient or modern river beds.

Above these alluvial deposits there is the usual alluvial surface soil, for the most part supporting a very dense vegetation.

The tin deposits hitherto found are all stream tin. No lodes have yet been worked, though there are some in the mountains round the sources of the Perak River. The ore is almost always cassiterite in small abraded crystals. It is of a peculiar blackish-gray or brown aspect. Any person with a little experience would be able to distinguish between tin sand from Australia and that of Perak. The former is rather rich in gems, such as sapphires, rubies, hyacinths, garnets, topazes, and zircons. I have never seen any in Perak; but there is a good deal of fluor-spar, tourmaline, and less frequently wolfram.

The most of the workings are on the western slopes at the foot of the mountains. I cannot recall any instances of mines on the eastern slopes, but the wash or drift seems to have been greater on that side.

The matrix of the tin seems to be in the upper part of the granite at its junction with the Palæozoic clays. In the lower part of the clay there is also a small quantity of tin.

In the drift the tin is always found in nearly the lowest levels, lying in one or two strata from one foot to five feet thick. It is mingled with fine drift sand and gravel. Its position is, I think, due to the repeated sifting and washing it has been subject to in the stream bed. But as it is generally covered by from ten to thirty feet of material destitute of tin, the inference is that only one part of the granite was very rich in the metal.

The stream tin deposits lie upon (1) kaolin clay, or partly decomposed granite; (2) granite; (3) Palæozoic sandstones and clays. In the latter case the stream has come from the denudation of a portion of the same strata on the upper slopes of the hills.

On the highest granite ridges, or those above 5000 feet, there is found a distinct vegetation. Three or four of the genera are Australian (*Melaleuca*, *Leptospermum*, *Podocarpus*, *Leucopogon*), and two of the species (*Leptospermum* and *Leucopogon*) are common Australian forms. Similar facts have been observed in Borneo, but I have not heard that they had been observed in the Malay peninsula. Nothing of the kind is seen on the lower slopes of these mountains even 100 feet below the summit. This Australian flora may be the relics of an ancient flora, which once included the Eastern Archipelago. But it does not appear why the species should be confined to the tops of the mountains. They grow in a much warmer climate in Australia.

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[1] Prof. Cayley, when returning thanks, distinctly waived the claim of priority in favour of the late Prof. Boole. See also Salmon's "Higher Algebra," p. 294.

There are no table-lands in Perak; the mountains are all sharp ridges. There is not the slightest sign of any recent upheaval of the coast-line, while the evidence of subsidence is equally absent. But the land is rapidly encroaching on the sea owing to the immense alluvial wash brought daily from the mountains in this land of heavy rains. Thus the shores are fringed with large mangrove swamps which yearly extend, and the Straits of Malacca form a shallow sea full of mud banks and shoals. The seas are consequently rather poor in certain forms of marine life to which muddy sediment is unfavourable.

Though the tin has been worked for centuries, only a comparatively small portion of the country has been worked out or worked at all. I consider that the deposits in Perak are practically inexhaustible. The mining industry is almost exclusively in the hands of the Chinese, who are almost the perfection of colonists for a country like this. Malays are not good miners. Gold is found associated with tin, but small, scaly, in sparing quantity, and only in one or two places.

There are only two instances known to me of the occurrence of recent volcanic rocks: one is in the Kinta River valley, the other on the western face of a small group of mountains not far to the east-south-east of the island of Penang, and near the Karau River. The rocks appear to be basaltic dykes, but the thick jungle and surface weathering prevented a proper examination.

The mountain system of this native State consists of detached groups of mountains which cover the west side of this part of the peninsula, an almost continuous range close to the sea in the Straits of Malacca. These groups of mountains form parallel chains about thirty miles long, with a direction a little oblique to the true meridional line. Sometimes they are wholly detached groups, so as to allow rivers from the eastward to pass between them. Such an instance is seen in the ranges between the Kinta and Perak rivers. This group terminates to the north so as to allow the River Plus to pass to the westward and to the south so as to give an outlet to the Kinta. Both rivers join the Perak River, which flows round another group (Gunong Bubu), and then flows into the sea in the Straits of Malacca.

The islands of the coast, such as the Dindings and those off the State of Keddah (Pulo Leddas, Pulo Lankawi, and Pulo Buton, known as the Buntings), are probably portions of similar groups, and so are Pulo Penang and the attendant islands. These groups and those on the mainland usually run in sharp parallel ridges, variously modified by oblique spurs, which at times connect the main chains forming watersheds which throw off small streams north-east and south-west.

The following are the principal groups of mountains known to me, beginning at the south:—

Dindings Islands.—Off the coast in front of the Dindings River (*Dinding*, Malay for boundary or partition), lat. 4° 12′ N., there is a series of islands of moderate elevation not exceeding 1000 feet in their highest peaks. They are granite, rich in tin, with a little fine scaly gold. They are densely clothed with jungle, and have fringing reefs of coral. I have visited three or four of these islands, and they are all of the same character.

On the mainland there is a cluster of hills called the False Dindings, from the fact that at a short distance they look like islands. These are also granitic, and tin occurs in the alluvial beds derived from them. They give rise to small rivers, such as the Dindings and its tributaries.

Gunong Bubu.—North-east of this group, but quite detached from it, is a series of parallel mountain ridges with a uniform trend of north-north-east. These ridges are eight or nine in number. The central one is the highest, culminating in Mount Bubu, a fine peak of about 5600 feet elevation. All the ridges are granitic, with occasional patches of metamorphic schists, all more or less rich in tin. A remarkable character in this range is that all the ridges are extremely steep, and frequently interrupted by granite precipices of 1000 feet and more. Gunong Bubu is only accessible in one or two places, the summit being surrounded by escarpments of rock of great height.

Many small streams join the Perak River and the sea from this range. The Kaugsa and Kenas both flow into the Perak to the eastward. In an ascent made by me to the summit of Mount Bubu I was able to explore some of the sources of both these rivers, which afford a home to many a rhinoceros, but few other animals except monkeys (*Hylobates*, *Semnopithecus*, and *Macacus*). The rivers descend many hundred feet in a series of cascades, giving rise to some of the finest scenery in the Malay peninsula.

North of Mount Bubu this group of ridges falls away abruptly, leaving a narrow pass (Gapis Pass) between them and the next group. This pass is about 400 feet above the level of the sea, and therefore too elevated to permit of any river outlet.

Mount Poudok.—In Gapis Pass, or rather at the eastern end of it, there is an isolated hill of highly crystalline limestone. It is an outlier of the great Palæozoic limestone formation already referred to. It is about 400 feet high, and quite precipitous. Its junction with the granite or Palæozoic clays is not visible. Its bright blue and red precipices crowned with dark-green jungle make it a singular and beautiful object, but there are many similar in the State.

Mount Ijau.—North of Gapis another group of ranges succeeds, culminating in Mount Ijau (Malay for green) at about 4400 feet above the sea. This cluster of ridges appears to me to be of nearly the same dimensions as the Mount Bubu group, but not so high by 1000 feet or so. I estimate that each group is from twenty to twenty-five miles long, and fourteen to sixteen broad, covering an area of about 400 square miles. This, however, is only a rough estimate formed from views I have been able to obtain from the summits of other mountains. I have not been able to examine personally the termination of the Mount Ijau group on the north. From the sea one is able to perceive a distinct pass like that of Gapis. It is probably about the same height, and does not form the outlet of any river from the eastern side.

Kurau Group.—North of Gunong Ijau is another group, which I do not know how to distinguish except that it forms the watershed of the Kurau River. Its highest point is a mountain which is also called Ijau by the Malays. I have not ascended the peak, but it seemed to me less elevated than Mount Ijau to the south.

Mount Inas.—What the Malays of Keddah call Mount Inas is the highest point of another detached group north of the Krian and Selama Rivers. I have been within a few miles of the foot of this mountain, and it seemed to me to be somewhat over 4000 feet high, and the highest point of an isolated group of ridges.

Keddah Peak.—North of Mount Inas, in the State of Keddah, there is, close to the sea, a detached group of mountains, at the foot of which the Keddah River flows. Keddah Peak is the highest summit,—probably over 4000 feet high. This is in what is called Lower Siam, in which I have only travelled to a very trifling extent north of the Krian River, the boundary of Perak State. In the north of Perak, near Patani, we have other groups of mountains. An Italian explorer named Bozzolo, who has lived many years in Siam, assures me that he has travelled round the Gunong Kendrong group at the head of the Perak, and that it is quite detached from any other hills.

Perak River.—The whole of these groups are sufficiently connected to prevent any drainage from the central range flowing directly to the west coast of the peninsula. Thus the Perak River, which has its sources in the Keddah and Patani Mountains flows to the southward for over 180 miles. In its course it is joined by two important rivers from the eastward, namely, the Plus and Kinta.

Plus River.—The Plus River has its sources in the high mountain groups east of Mount Inas, and in the main range. It flows round the southern end of a group called by some the Bukit Panjang Range, and then joins the Perak.

Kinta Ranges.—South of this junction is a group of mountains called by some the Kinta Ranges. This group is about twenty-five miles long. It is perfectly detached from all the others, having a generally north and south direction, but sending off spurs from its west side a little to the west of south. The group is entirely granitic, but on its lower slopes has thick deposits of limestone belonging to the formation already referred to, above and below which tin is worked. For about twenty-five miles this range separates the valley of the Perak River from that of the Kinta, which flows on its eastern side. The highest peaks rise to about 3750 feet above the sea, and give rise to small streams which all flow into the Perak. There is a remarkable uniformity in three or four of the highest summits, which are about the centre of the chain, Mounts Merah (red), Prungin, &c. They are all within a few feet of the same height. From these mountains the range falls away gradually to the south, and sends off two considerable spurs to the south-west. Where it ceases the River Kinta joins the Perak.

Kinta Valley.—The valley of the Kinta River is about as wide as that of the Perak. The river flows, like the Perak, on the eastern side of the valley. The eastern tributaries are many and important. On the sides limestone granite and schistose slates crop out. To the eastward there are many detached hills of limestone fronting the main central chain. They form very characteristic features in the landscape, from their precipitous outline, and the brilliantly coloured faces of blue, green, and bright red rock. They are also distinguished by a different vegetation.

Perak Valley.—The valley of the Perak River is bounded by the groups of mountains already described on the west; on the east by the Kinta Range, and north of the Plus by the Bukit Panjang Range. The river flows on the eastern side of the valley; this is owing to the many spurs and outliers on the eastern sides of Mounts Bubu and the Ijau Ranges. It seems as if there had been much less denudation on the eastern than on the western sides of the range. This may be owing to the prevailing rains falling more abundantly on the western than on the eastern sides of the mountains.

As a consequence of this the tin workings appear to be, with little exception, on the western sides of the ranges, where the waste and wash has probably been greater.

Batu Kurau.—Between Mount Bubu Range and Mount Ijau Range and the sea there are no hills except small outliers, mostly of Palæozoic clay, which have evidently belonged to the ranges. But north of the Larut River there is an isolated limestone mountain near the Kurau River. This is called Batu (stone or rock in Malay) Kurau. It is very similar to Mount Poudok in the Gapis Pass. It is quite unconnected with the main range, and rises out of the plain between the spurs which form the valley of the Kurau River. There is also a small detached range dividing the valley of the Krian River from that of the Kurau.

Main Range.—Of the main range I know but very little from personal observation, having only visited it at Goping, and at the limestone hills, where the tin is worked on the Diepang River. But I have travelled along the most of the Kinta Valley skirting the base of the range either on foot or in boats. I have also traced the valley of the Kampar River. The geology is like the rest of the country, mainly granite, slates, and limestone, with traces of basaltic rocks. The general structure of the range can best be judged from some of the mountains to the westward. It forms a most imposing boundary to the whole of the western horizon. In the north, about the sources of the Plus River, there is a mountain of rounded outline, probably over 6000 feet high. The range there declines a little, with a somewhat serrated outline, but generally over 3000 feet. At a point corresponding with the latitude of about the centre of the Kinta Range, or opposite the Gapis Pass, the chain increases in elevation to perhaps over 5000 feet, and in the distance is seen a peak which must be over 8000 feet high. I know no name for this hill, but it is the most distant mountain usually seen. South and west of this the chain rises into a grand cluster of peaks, the highest of which is over 7000 feet. This is Gunong Robinson. It looks higher than the Sugar-Loaf Hill as seen from Gunong Bubu, but then it is much nearer. From Gunong Robinson the range declines to the southward, but is still a bold series of picturesque peaks, many of which must be over 6000 feet. It has been asserted by more than one observer that to the south of the point where the range is lost sight of from Arung Pura, there is a high mountain occasionally visible higher than any other in the main range, and probably over 12,000 feet. This I have not seen, but I am convinced that there are many things yet to be learned about the most elevated portions of this mountain chain. Seen from any point of view, it forms a magnificent mountain prospect. Its mysterious unexplored recesses are rendered more gloomy than any scene in the world from the dense forest and the masses of vapour and cloud with which they are always clothed. A few savage Sakies are the only inhabitants. I may add that perhaps in no country in the world is exploration rendered so difficult from the extraordinary thickness of the jungle and the steepness of the mountain ridges which unceasingly cross the traveller's path.

Penang, September 8 J. E. TENISON-WOODS

A NEW APPLICATION OF SCIENCE

DR. FERRIER'S researches on the brain, to which we have often drawn attention in these columns, have lately received an application of the most startling character. What this application is cannot be better stated now than in the accompanying letter, signed "F.R.S.," which appeared in Tuesday's *Times*. We shall return to this subject next week.

"While the Bishop of Oxford and Prof. Ruskin were, on somewhat intangible grounds, denouncing vivisection at Oxford last Tuesday afternoon, there sat at one of the windows of the Hospital for Epilepsy and Paralysis, in Regent's Park, in an invalid chair, propped up with pillows, pale and careworn, but with a hopeful smile on his face, a man who could have spoken a really pertinent word upon the subject, and told the right rev. prelate and the great art critic that he owed his life, and his wife and children their rescue from bereavement and penury, to some of these experiments on living animals which they so roundly condemned. The case of this man has been watched with intense interest by the medical profession, for it is of an unique description, and inaugurates a new era in cerebral surgery; and now that it has been brought to a successful issue, it seems desirable that a brief outline of it should be placed before the general public, because it illustrates vividly the benefits that physiological explorations may confer on mankind, shows how speedily useful fruit may be gathered from researches undertaken in the pursuit of knowledge and with no immediate practical aim, and reveals